UCRL-PROC-200964

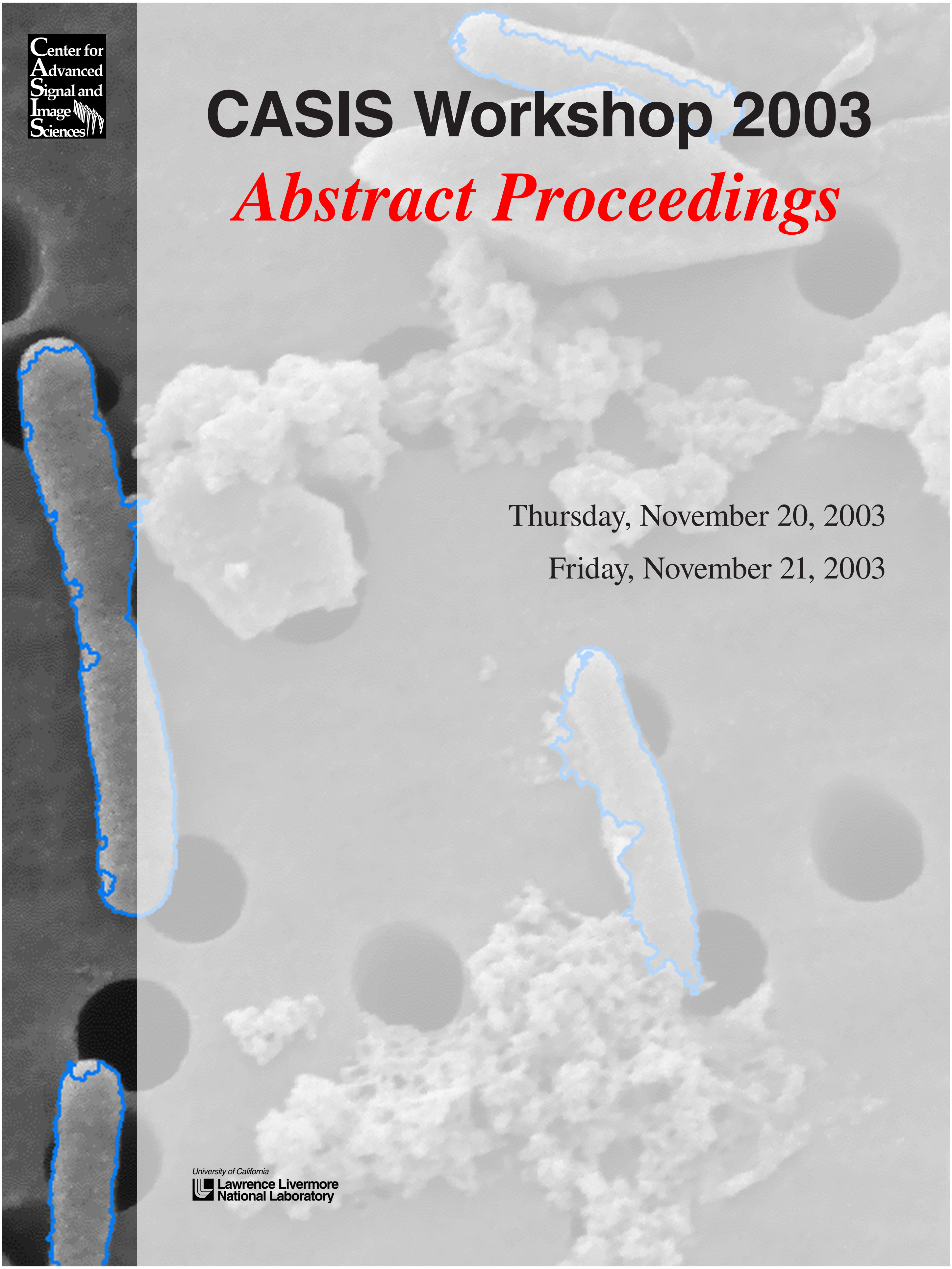
LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

C.A.S.I.S. Workshop 2003 Abstract Proceedings

S.G. Azevedo

November 14, 2003

Signal and Imaging Sciences Workshop
Livermore, CA, United States
November 20, 2003 through November 21, 2003



Center for Advanced Signal and Image Sciences

CASIS Workshop 2003

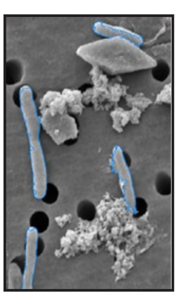
Abstract Proceedings

Thursday, November 20, 2003

Friday, November 21, 2003

University of California
Lawrence Livermore National Laboratory

This work was performed under the auspices of the U.S. Department of Energy, National Nuclear Security Administration by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.



The background image is a scanning electron micrograph (SEM) of Bacillus thuringiensis ssp. israelensis bacteria (the highlighted rods), bacterial protein toxin crystals (the diamonds) and cellular debris. The B. thuringiensis is used in studies as a surrogate for B. anthracis, the causative agent of anthrax. The image was processed to identify B. thuringiensis using the Image Content Engine (ICE) under development at LLNL. ICE consists of image analysis software designed to rapidly search massive databases of large-format imagery for suspect structures. It is currently funded as a Laboratory Directed Research and Development Strategic Initiative (LDRD-SI) project.

Image courtesy of David Paglieroni
Data courtesy of Charlene Schaldach

Welcome

Table of Contents

Adaptive Optics

NIF Imaging

Scientific Data Mining

Applied Signal Processing/Control

Keynote Abstract

Medical Imaging Frontiers

Dr. Thomas F. Budinger

Thirty five years ago, while in the neutron cross section group led by Robert Howerton at LLNL, the concept of reconstructing a three dimensional spatial distribution from its projections onto two dimensional planes was tackled by some of us using three now well known methods: simple back projection, Fourier projection theorem methods and iterative least squares algebraic reconstruction. The method of iterative least squares reconstruction was implemented on patient data in the early 1970s using photons from radionuclides detected by the Anger Camera. The method useful for computed tomography was modified to include the attenuation of the photons from an unknown source through an unknown attenuation distribution (a problem thought to be intractable until 1974). These methods along with a multitude of other methods developed by my small group of Ronald Huesman, Grant Gullberg, William Greenberg and Stephen Derenzo were prepared as a library with examples in FORTRAN, RECLBL. Those codes were found useful for computed tomography, geophysical problems and plasma confinement research topics in addition to their use in Nuclear Medicine. The codes were used even in the early days of magnetic resonance imaging when back projection of filtered projection data were used before the incorporation of phase encoding methods. In 1970s computed tomography of a single section of the brain required 4 minutes for single photon tomography or positron emission tomography about 30 minutes were required. Even proton and helium ion tomography were accomplished in the 1970s but with more that 2 hours of data acquisition. Thirty years later CT systems deliver 16 sections per second with 1 mm resolution and PET systems acquire 40 sections with about 4 mm resolution in 5 minutes. Computation times have reduced from 18 hours on the CDC 6600s and 7600s for gated, list mode data to less than 5 minutes in the last 30 years. Similar ratios of improvement have benefited ultrasound and magnetic resonance imaging.

So what are the constant elements of imaging and what are the elements which change in the future? By the constant elements I refer to those principles which are time or history invariant (e.g., Fourier projection theorem, methods for detection of single or limited number of sources are not optimal for continuous distributions; limited angle or incomplete data are missing sources, which cannot be set to zero; back projecting data into unnatural pixels or voxels will result in erroneous reconstructions, etc.). The elements, which will change in the future include improvements in 5 attributes of an imaging modality: spatial resolution, time resolution, volume of the imaged object, signal to noise, contrast sensitivity. Signal to noise improvements include methods to reduce scatter in photon imaging as well as improvement in data transmission and processing before digitization. The one attribute of most importance in the selection of the imaging modality to solve a problem (e.g., electric source imaging vs electron density imaging) is contrast sensitivity because it is this property which distinguishes one method from another and it is this attribute, which can be amplified as is illustrated by the injection of high atomic number contrast agents or radionuclides, which target specific tissues. A new concept in imaging is the use of a pro-targeting agent such as a chemical which will seek the target of interest or be modified by the environment of interest such that when a signaling tracer or contrast agent is injected later that agent will attach only to the modified or sequestered pro-targeting agent.

The intent of this presentation is to show the evolution of PET, SPECT and MRI from the perspectives of spatial resolution and contrast sensitivity. The limits of SPECT at 1 mm resolution for animal studies, of PET at 2 mm resolution for human studies and of MRI at 50 micrometers for the surface of the brain will be presented in the context of new scintillation detector materials, new imaging gantries and magnetic fields of 12 T. A presentation of an algorithm for Fresnel coded aperture imaging will initiate a discussion of other coded aperture approaches of interest to LLNL.

The Center for Non-Destructive Characterization

Computed Tomography at Advanced Light Source/LBNL

John Kinney

ABSTRACT NOT RECEIVED BY AUTHOR

Nondestructive Characterization Technologies for Metrology of Micro/Mesoscale Assemblies*

Amy Waters, Robin Hibbard, Matthew Bono, and Harry Martz

UCRL-ABS-200285

Micro/mesoscience is an emerging area of science and engineering, a major part of which involves the study of assemblies with small to very small dimensions (~ mm), features and structures (~ µm). Advances in micro/mesoscience will pose new challenges in experimental physics and engineering in general and will lead to new ways of information processing; require new materials with pertinent properties; and lead to new techniques for medical diagnostics and treatment. We have applied known Nondestructive Characterization (NDC) methods to "see" inside or image micro/mesoscale-size materials, components and assemblies. This will help enable a fundamentally new set of methods that can serve micro/mesoscale science and engineering. A set of mesoscale reference standards were built and documented in an effort to help quantify existing NDC techniques. The two reference standards were built using materials that vary widely in composition (low-Z to high-Z), density (~0.03 to 20 g/cm3, i.e., aerogels to fully dense metals), geometry (planar to spherical), and embedded features (joints to subassemblies). Higher spatial-resolution (~1.5 to 6 µm) computed tomography (CT) data was acquired for the reference standards using a LLNL CT system as well as a commercially available CT system. These preliminary results will be presented along with a discussion of existing NDC technologies, and requirements that may exist or must be developed to quantitatively characterize mesoscale objects.

X-ray Phase Contrast Imaging

Anton Barty

UCRL-ABS-200876

Absorption contrast imaging, which relies on the attenuation of X-rays as they pass through material, has been the dominant imaging mode in X-ray imaging since the discovery of X-rays by Röntgen in 1896. Absorption imaging is extremely powerful, however it is only effective when the sample is absorbing and provides limited contrast when imaging light-element materials such as biological tissue, and is often poor at revealing high spatial frequency features superimposed on large structures of low-spatial frequency.

More recently there has been a growing interest in various forms of X-ray phase contrast imaging. Phase contrast renders visible changes in the refractive index of the sample. It offers the advantage of being particularly sensitive to high spatial frequency features, and enables enhanced contrast imaging of weakly absorbing or non-absorbing samples. Phase contrast is always present to some extent in the collected data and must be accounted for in both forward and inverse models of the imaging system. As both laboratory and synchrotron based X-ray sources become more coherent it is increasingly important to include phase effects when modeling an X-ray imaging system.

This talk will provide a brief introduction to X-ray phase contrast and will describe simple mechanisms for obtaining phase contrast images in a laboratory setting. The importance of including phase effects in both forwards and inverse image system modeling will be illustrated using data from a microfocus point-projection imaging system (K-CAT) at LLNL and it's application to the imaging of low-Z materials will be described.

Guided Wave Inspection of Multi-layered Structures

M.J. Quarry

UCRL-ABS-200281

This study investigates the utilization of guided waves for inspecting structures that consist of multiple layers. Advances have been made in recent years using guided waves to inspect single layer structures, such as pipes, tubes, and aircraft structures. Multi-layered structures present many new aspects to guided wave propagation. A theoretical understanding of what modes exist, how do the modes behave, and what factors influence them needs to be acquired for many applications. Experiments must be carried out to evaluate potential for practical applications. Examples of practical applications include coated pipes, composites, diffusion bonded aircraft structures, and microelectronic structures. This work is a fundamental study of ultrasonic guided waves in multi-layered plates. Experiments were conducted on multi-layered plates to demonstrate defect detection in layer of interest of a multi-layered structure by preferentially exciting modes with sufficient energy in that layer. Analysis of the dispersion curves show that some modes are more attractive candidates than others based on their displacements and energy distribution across the structure. Experimental results show that sweeping frequency and phase velocity can be performed to find suitable modes for inspecting a layer of interest for a given multi-layered structure.

Application of Seismic Techniques to Ultrasonic Non Destructive Evaluation of Multilayered Elastic Structures

Karl A. Fisher

UCRL-ABS-200762

A wealth of useful algorithms and techniques have been developed over the past 90 years for the task of converting seismic data into accurate images of the subsurface geology. Seismologists have long dealt with the challenges associated with creating accurate images in this complex environment. Some of the more common errors in seismic imaging are a result of refraction and multiple reflections from impedance changes between layers, unknown sound speeds, unknown geometries, noisy data and limited access. Similar challenges are also faced by researchers using ultrasonic non-destructive evaluation (NDE) to investigate multi-layered elastic structures for flaws. Fortunately, for most NDE applications there is information about the part in the form of material properties and geometry that can be applied to mitigate the aforementioned errors. The focus of this presentation will be to illustrate the utility of traditional seismic approaches in conjunction with experimental ultrasonic data from a 32-channel array to detect flaws in a multi layered elastic structure.

3D Rendering of Acoustics Data

Steve Benson

ABSTRACT NOT RECEIVED BY AUTHOR

Vibrothermography: A Combined Infrared + Ultrasonic Non-Destructive Inspection Technique

Michael W. Burke

ABSTRACT NOT RECEIVED BY AUTHOR

Photothermal Imaging

Robert Huber, Diane Chinn, Chris Stolz, and Carolyn Weinzapfel

UCRL-ABS-200516

Photothermal imaging is a nondestructive evaluation technique with a number of applications, including the locating of certain unwanted particles near the surface of an optic. For optical systems employing high power lasers, the unwanted particles may be problematic if their absorption at the laser wavelength is significant. Strong absorption can lead to distortion of the laser beam, or even damage to the optics. Photothermal imaging is basically an optical pump-probe technique. For this particular work, a pump laser beam is used to illuminate an area at the surface of a coated optic, and any absorbers in the coating will heat up with respect to the surrounding material if there is a large difference in absorption causing localized thermal bumps. A probe laser beam of a different wavelength incident on the optic at the pump site will be diffracted by the thermal bumps. Studies were performed on coated optics to look for unwanted particles originating during the coating process. This work has been directed at increasing the speed of the photothermal technique, primarily through moving from single point to array detection.

Process Development and Implementation of Non-Destructive Evaluation (NDE) to Finite Element Analysis (FEA) Coupling for Numerical Analysis

Edwin J. Kokko, Diane J. Chinn, Harry E. Martz,
Robert M. Sharpe, David H. Chambers, Steve J. DeTeresa

UCRL-ABS-200482

Finite element analysis models are typically used to evaluate component designs and to predict the results of test scenarios. Most finite element analysis models are currently built using idealized object design specifications and do not take into account material flaws (including cracks, voids and inclusions) or geometric irregularities (including warping) which exist as a result of materials and manufacturing processes and service conditions. Even though the most accurate representation of the object is desired, the additional steps required to detect, identify, and model material and geometry deviations in the object's "as built" configuration is currently to time consuming and difficult for most applications.

In FY2003, LLNL engineers developed a "roadmap" linking all the key steps between the initial evaluations of an object using nondestructive techniques (NDE), such as X-ray CT and acoustic tomography, through the analysis itself using engineering finite element codes at LLNL. Key steps in the "as-built" modeling process "roadmap" include: multi-modal and multi-source NDE data collection, image reconstruction and artifact removal, multi-modal NDE data fusion, image segmentation, feature extraction (based on analyst requirements), mesh generation, and object analysis using finite element codes (structural, electro-magnetic, thermal, etc). Identifying specific techniques (within each key step) to use for specific classes of analysis problems is the crux of the problem. The ultimate project goal is to eventually semi-automate the process by aligning and enhancing existing time saving tools and techniques for each key step.

As part of the project, several test objects have been conceptualized, manufactured, and imaged using several NDE techniques. The NDE data sets that have been collected will be used in FY2004 to test the techniques that will be implemented for each of the key steps in the process. Evaluating algorithms to correctly "fuse" multi-modality NDE data sets for "as-built" components, methods to extract desired features from images, and methods to translate image information into a form easily manipulated with lab analysis code pre-processors, are areas that will be focused on in FY2004.

Nondestructive Characterization of Ceramic Processing Defects

Diane Chinn, Clint Logan, Michael Burke, Sean Lehman

UCRL-ABS-200281

Nondestructive techniques are well established for the detection and localization of discrete defects such as individual cracks or voids. However, the powder processing techniques used to manufacture ceramic components can result in regions of 'distributed' defects such as microporosity, excess sintering aid, unsintered agglomerates, and microcracking. These distributed defects are different from those occurring during processing in metallic systems and often appear to NDC techniques as variations in the apparent bulk properties of the material (i.e. variations in the density or elastic moduli).

Currently, assessment of ceramic parts is accomplished by qualitatively correlating bulk material properties such as pore size, grain size, and compositional variations to an NDC response. This is often based upon a priori knowledge of manufacturing conditions. By providing a correlation between ceramic microstructure and NDC response, we gain a better understanding of the NDC response and obtain more information on NDC when used in other applications. In addition, this improved understanding allows better interpretation of ceramic inspection data and provides a basis for modeling the effects of the features identified by NDC.

In this study, response parameters from five nondestructive characterization (NDC) modalities - acoustic, X-ray, optical, thermal and surface - are correlated with microstructural inhomogeneities in two types of ceramics with six types of defects. These inhomogeneities arise from inconsistencies during the manufacturing process, and can potentially reduce the performance of the material. The overall approach is to manufacture ceramic specimens with intentional flaws, apply NDC methods, destructively section the flawed regions, then correlate the NDC results to micrographs of defects.

Preliminary Vibrothermographic Inspection of NASA Shuttle Leading Edge Composite Panel

Michael Burke

ABSTRACT NOT RECEIVED BY AUTHOR

Applied Imaging

Electrical Resistance Tomography for Subsurface Imaging

William Daily and Abelardo Ramirz

UCRL-ABS-200542

Geophysical electrical resistance tomography (ERT) is a method of imaging subsurface structure and processes. Using an array electrodes in ground or on the surface, electrical currents are injected into the subsurface and the resulting voltages are measured. From these data, the distribution of electrical resistivity is calculated by minimizing the misfit between the data and voltages calculated from a numerical model. Depending on the completeness of the sampling, either a two- or three-dimensional reconstruction is possible. The method has been used to image underground structures such as barriers designed to confine the spread of contaminated ground water. However the most powerful approach has been to image subsurface time dependent processes. For example, it is possible to follow the movement of water plumes as they move away from an underground leaking storage tank. The most recent application has been to follow the movement of fluids in an oil reservoir over 5000 feet deep. The basic methodology of ERT will be described and then it will be illustrated by a few recent applications.

3D Wavelet-Based Image Analysis of Chromosomes and Cracked Pipes

William C. Moss, LLNL

John Sedat and Sebastian Haase, UC San Francisco

UCRL-ABS-200429

Although it is well known that chromosomes contain DNA, no one knows the structure of a chromosome that is tightly packed in a cell nucleus. The best data to date consist of 3D electron microscope tomographs (~1nm resolution). These tomographs have a lot of background noise (arising from nonspecific staining), so the problem is analogous to determining the structure of an object that is buried in a cloud of nearly the same density material as the object. To date, no methods (Fourier, correlation, model fitting) have been successful in determining structural details. The 3D wavelet-based filter described here is a new approach at solving the chromosome structure problem. We have used the filter to extract structural content from 3D electron microscope tomographic and 3D optical images. The filter has no adjustable parameters, other than the characteristic size of the feature of interest. Consequently, the filter can be easily used to analyze any 3D (or 2D) data. For example, we use the filter to identify a wavy crack on the inside of a hollow pipe. Many other applications may be possible.

Stochastic Inversion of Electrical Resistivity Changes Using a Markov Chain, Monte Carlo Approach

A.L. Ramirez, J. J. Nitao, W. G. Hanley, R. Aines, R. E. Glaser,
S. K. Sengupta, K. M. Dyer, T. L. Hickling, W. D. Daily

ABSTRACT NOT RECEIVED BY AUTHOR

UWB Radar Camera

K. Romero, J. Chang, F. Dowla

ABSTRACT NOT RECEIVED BY AUTHOR

An Overview of the Image Content Engine (ICE) Initiative

Chuck Grant

ABSTRACT NOT RECEIVED BY AUTHOR

Coherent X-ray Diffractive Imaging: Applications and Limitations

Stefano Marchesini

ABSTRACT NOT RECEIVED BY AUTHOR

SPEDEN: Reconstructing Single Particles From Their Diffraction Patterns

*S.P. Hau-Riege, H. Szoke, H.N. Chapman, A. Szoke, H. He,
S. Marchesini, M. Howells, U. Weierstall, A. Noy, and J.C.H. Spence*

UCRL-ABS-200890

SPEDEN is a computer program that reconstructs the electron density of single particles from their x-ray diffraction patterns, using an adaptation of the Holographic Method in crystallography. (Szoke, A., Szoke, H., and Somoza, J.R., 1997. Acta Cryst. A53, 291-313.) The method, like its parent, is unique that it does not rely on "back" transformation from the diffraction pattern into real space and on interpolation within measured data. It is designed to deal optimally with sparse, irregular, incomplete and noisy data. It is also designed to use prior information for ensuring sensible results and for reliable convergence. In this presentation we describe the theoretical basis for the reconstruction algorithm, its implementation, and quantitative results of tests on synthetic and experimental data. The program could be used for determining the structure of radiation tolerant samples and, eventually, of large biological molecular structures without the need for crystallization.

Communications and Networking

Low Power, Rapidly Deployable Network of Radar Detection and Communications Sensors (Guardian)

Peter Haugen

ABSTRACT NOT RECEIVED BY AUTHOR

Position Estimation of Transceivers in Communication Networks

Claudia A. Kent and Farid U. Dowla

ABSTRACT NOT RECEIVED BY AUTHOR

Optical Code Division Multiple Access (O-CDMA) Technology Demonstrator for Matrix Codes

Vincent J. Hernandez

ABSTRACT NOT RECEIVED BY AUTHOR

Experimental Design and Processing for Time-reversal Communications in a Highly Reverberant Environment

Brian Guidry

UCRL-ABS-200793

A suite of experiments has recently been conducted to validate the utility of using Time-Reversal (T/R) theory to solve a communications problem for highly reverberant environments. This paper discusses the design and layout of those experiments as well as experimental equipment criteria and selection. Solutions to problems arising from equipment limitations encountered during the experimental design process are examined. The signal processing used to extract information from gathered data is described and it is shown that communications receivers utilizing T/R theory can be used to accurately reproduce messages broadcast through hostile, reverberant communications channels.

Adaptive Optics

MEMS Adaptive Optics Phoropter

Steve Jones

ABSTRACT NOT RECEIVED BY AUTHOR

Recent Results from Adaptive Liquid Crystal Based Phoropter

Abdul Awwal

UCRL-ABS-155658

This is a follow up talk from last years CASIS presentation. In this talk we present new results of wavefront compensation using human subjects and outline design criterions for possible new generation liquid crystal (LC) based phoropters. The dynamic range of the Shack-Hartmann wavefront sensor, actual speed of the liquid crystal SLM, the operating wavelengths of the liquid crystal spatial light modulator are important parameters to be considered in the new design.

Reference:

1. A. A. S. Awwal, Brian Baumann, Don Gavel, Scot Olivier, Steve Jones, Dennis Silva, Joseph L. Hardy, Thomas Barnes and John S. Werner, “Characterization and Operation of a Liquid Crystal Adaptive Optics Phoropter” presented in conference on Astronomical Adaptive Optics Systems and applications, SPIE Vol, 5169, August 2003.

High Speed Turbulence Correction with MEMS-based Spatial Light Modulators

Kevin Baker

UCRL-ABS-200893

Both laboratory breadboard and field test results of a high-speed adaptive optics system are presented. The phase conjugate engine for this adaptive optics system is based on a quadrature interferometer, which directly measures the turbulence induced phase aberrations and a MEMS-based piston-only correction spatial light modulator with 1024 actuators. The overall system achieved correction speeds in excess of 800 hz and Strehl ratios greater than 0.5.

Enhanced Surveillance Using Speckle Imaging

Carmen Carrano

UCRL-BOOK-200738

In my talk I will give an overview of FY2003 activities and results using speckle imaging techniques for enhancing the resolution of extended scenery acquired over horizontal and slant paths through the atmosphere. These activities included imaging of vehicles from 20-40 km, low-light horizontal path imaging of personnel, and work on developing a near real-time speckle imaging capability.

Signal Processing and Adaptive Optics for Extra-solar Planet Detection

Lisa Poyneer

ABSTRACT NOT RECEIVED BY AUTHOR

Intracavity Adaptive Correction of a 10kW, Solid-state, Heat-capacity Laser *

K. N. LaFortune, R. L. Hurd, E. M. Johansson, C. B. Dane, S. N. Fochs, J. M. Brase

UCRL-JC-154071-ABS

The Solid-State, Heat-Capacity Laser (SSHCL), under development at Lawrence Livermore National Laboratory is a large aperture (100 cm2), confocal, unstable resonator requiring near-diffraction-limited beam quality. There are two primary sources of the aberrations in the system: residual, static aberrations from the fabrication of the optical components and predictable, time-dependent, thermally-induced index gradients within the gain medium. A deformable mirror placed within the cavity is used to correct the aberrations that are sensed externally with a Shack-Hartmann wavefront sensor. Although the complexity of intracavity adaptive correction is greater than that of external correction, intracavity correction enables control of the mode growth within the resonator, resulting in the ability to correct a more aberrated system longer. The overall system design, measurement techniques and correction algorithms are discussed. Experimental results from initial correction of the static aberrations and dynamic correction of the time-dependent aberrations are presented.

* Supported by U.S. Army Space and Missile Defense Command

Resolution Boosting Filter for Spectrographs

David Erskine
UCRL-ABS-200810

In recent experiments the spectral resolution of the Lick Observatory echelle grating spectrograph has been doubled by insertion of a small optical element at the entrance slit and by special processing of the data, while maintaining the original slit width and keeping other aspects of the spectrograph the same. Essentially, we have "eyeglasses" that can be reversible inserted into the beam path of any spectrograph that boost its performance by factors of several. In addition to a resolution boost of 2-10x, the potential benefits include a dramatically improved resistance against systematic instrumental noise due to changes in shape of the light beam at the slit, aberrations of lenses in the spectrograph camera, and thermal or mechanical drifts of the CCD. Much more compact spectrographs per given resolution are now possible. A small Michelson interferometer having fixed delay is inserted into the light path. This filter embeds sinusoidal wavelength fiducials with the input spectrum, manifesting broad moire patterns that survive the slit blurring and are less sensitive to instrumental drifts. Special data processing recovers high spatial-frequency information that created the moire pattern, as well as the spectrum without the pattern. The technique is related to Fourier Transform spectroscopy, but has 100x times better photon signal to noise ratio, allowing use in astronomy and with other weak sources. Experiments to demonstrate 10x resolution boosting are underway.

A Procedure and Efficient Algorithm for Segmented Signal Estimation in Time Series, Image, and Higher Dimensional Data

Jeffrey D. Scargle, NASA Ames Research Center, Space Science Division

The problem of detecting statistically significant structure in time series data can be solved by obtaining the partition of the observation interval with the maximum posterior probability for a nonparametric, piecewise constant model. The result is the most likely step-function representation of the underlying signal. This procedure yields a denoised version of the signal with no explicit smoothing. It can reveal structure on any scale as long as the features are statistically significant.

We have found a surprisingly simple algorithm for obtaining the optimal partition of the interval, for any data type - including points, binned counts, and measurements at arbitrary times with a known error distribution. The case of point data modeled as a piecewise constant Poisson process is demonstrated in two modes: real-time and retrospective. The former will be used in future NASA space observatories to trigger on transient events, such as gamma-ray bursts, and the latter for automated processing of large databases of astronomical time series. The same algorithm also yields histograms in which the bins, determined by the data and not fixed ahead of time, are not necessarily evenly spaced.

The same approach can be used to model data in 2D, 3D and higher dimensional data spaces. For point data, the Voronoi tessellation of the data space provides an excellent data structure in which the Voronoi cells provide information about the local point density and its gradient. The optimum partition of the data space can be approximated by searching over the finite space of all partitions consisting of data cells assigned to separate partition elements, or blocks. Our 1D "Bayesian blocks" algorithm can be extended to this higher dimensional setting, to provide optimal piecewise representations of data in time O(N**2). Results will be shown for segmentation of 2D photon maps from gamma-ray telescopes, star catalogs from the 2MASS infrared survey, and 3D representation of the large-scale structure of the Universe based on the first data release from the Sloan Digital Sky Survey.

Collaborators include Brad Jackson, of San Jose State University, and Jay Norris, of the NASA Goddard Space Flight Center. I am greatful for support from the NASA Applied Information Systems Research Program, and the Woodward Fund and the Center for Applied Mathematics and

NIF Imaging

Overview of the NIF Automatic Alignment System

Karl Wilhelmsen

UCRL-ABS-155664

A primary goal of the NIF laser will be to perform 3 shots a day. It is expected that the heat from a shot and beam path instability will necessitate frequent realignment of 2300 optics. To meet the 3 shots per day goal, with the required time to conduct optics cooling, optics inspection and various other tasks, the entire laser must be automatically aligned in less than 1 hour. NIF will have 192 beamlines, 12000 alignment devices, 149 cameras, and a minimum of 20 types of image processing tasks. The automatic alignment system will be required to concurrently align all beamlines with minimal operator interaction. This presentation is an overview of the automated alignment system.

Characterization and Operation of Automatic Alignment Algorithms

Walter Ferguson, Wilbert McClay, Michael McGee, Mark Miller, Abdul Awwal

UCRL-ABS-155659

The development of reliable algorithm pertaining to automatic beam alignment at the National Ignition Facility (NIF) is a challenging problem. However, once these algorithms are developed they need to be characterized for their performance under various operating conditions such as lighting, aberrations and noise levels. One of the objectives of this characterization is to measure the maximum uncertainty under various imaging and noise conditions, so that one is ensured that the algorithm meets the required accuracy for NIF operations. The second objective is to use these uncertainty measurements in the algorithm so that during real time operation the operator will have an idea about the uncertainty of the measurement and may even terminate the process if it is too high. As an example, we discuss LM1_LM3 algorithm which determines the position of a series of two beam light sources for the NIF Project. This is accomplished by intelligent centroiding of the two light beam sources to sub-pixel accuracy. The relative positions of the image objects thus obtained are used to send commands that move the motors and attenuators to adjust the beam lines to the desired position. The performance of the LM1_LM3 algorithm was evaluated for an ensemble of nine hundred simulated images with varying image intensities, noise counts, as well as varying interference noise amplitude and frequency respectively from 200 to 50 amplitude and 10 to 50 counts of noise. The performance of the image data set had a tolerance well beneath the +/- 0.5-pixel for 3-sigma requirements for beam control.

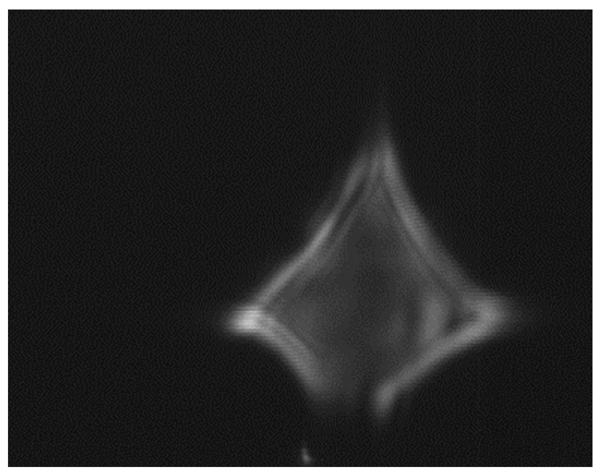
Composite AMPOF Filter Based Detection and Tracking of the Back-reflection KDP Images

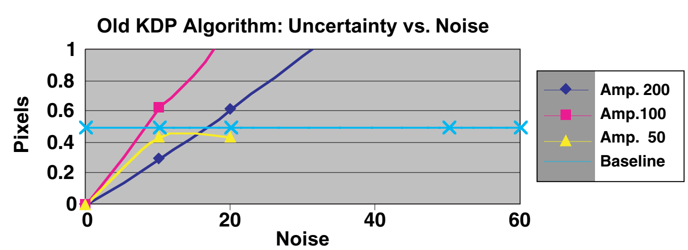
Abdul Awwal

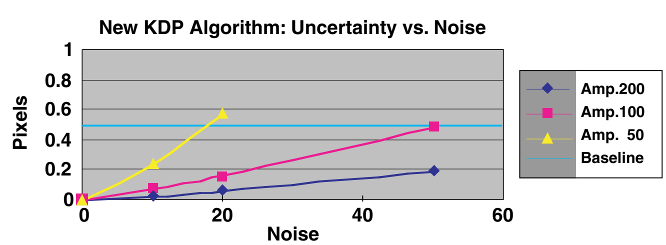
UCRL-ABS-155660

A new algorithm for determining the position of the KDP-back reflection image was developed. It was compared to the existing algorithm on 5 consecutive image frames. While the existing algorithm based on centroiding has a radial standard deviation of 9 pixels, the newly proposed algorithm based on classical matched filtering (CMF) and Gaussian fit to correlation peak provides a radial standard deviation of less than 1 pixels. Several upgrades of this new algorithm were implemented. First, the speed of the peak detection was improved from an average of 5.5 seconds to 0.022 seconds by using a polynomial fit peak detection. Secondly, the radial standard deviation was further improved from 0.59 to 0.507 pixels by utilizing a fuzzy filter[1,2]. Thirdly, the performance was enhanced even further by utilizing a composite amplitude modulated phase only filter (proposed in 1990 by Awwal et al. Ref. 3) producing a radial standard deviation of 0.267501[3-6]. The proposed technique was evaluated on 900+ images with varying degrees of noise and image amplitude as shown in Figure 1 and 2. The old algorithm currently running at the NIF facility produced a noise uncertainty of up to 18 pixels for amplitude 100 and rms noise of 50, the new algorithm for the same case produced uncertainty level below 0.5!

Evaluation results from 59 real NIF image files collected on beam line 315 from April 2003 to September 30, 2003 are also reported here. The feasibility of using a filter designed from the set of the original five consecutively taken images was evaluated and the performance of our approach was found satisfactory in terms of detecting the back reflection pattern. The variation in peak correlation intensity was found to be proportional to the image peak intensity. Thus a simple detection threshold is able to find the position of the back-reflected image. To ascertain its performance on simulated images with known position, an artificial image was created with a known centroid location. 900 images with varying noise such as Gaussian and interference noise and image amplitude were created from this original image. For the simulated image set, the uncertainty for the interference noise remained below the tolerance limit of 0.5 pixels. In addition, the difference between the average position calculated for a certain set and the true centroid was found to be less than 0.02 pixels for images with intensity 100 and 200. They were found to be bounded by the theoretical maximum of $3\sigma/\sqrt{(n)}$, where σ is the standard deviation of each set[7]. In the future, it is possible to reduce the operation time even further by switching to a target tracking algorithm[8], once the control loop is closed. If the variation of the pattern is very high, the filter could be designed to be classification type filter distinguishing between multiple classes[9,10].







Acknowledgement:
The author acknowledges Paul Wegner and Thad Salmon for having useful discussions about the KDP back reflection pattern; Wilbert McClay for performing statistical analysis on the 900 images, Walter Ferguson for supplying simulated KDP image and Michael McGee for generating noise added image sets.

Reference:

1. M. Rahman, A. A. S. Awwal, and K. Gudmundsson, "Composite filters for search time reduction for 3D model based object recognition," in Photonic Devices and Algorithms for Computing V, K.M. Iftekharuddin and A. A. S. Awwal Editors, Proc. of SPIE, Vol. 4201, 2003.
2. A. A. S. Awwal, M. Tabrez, M. Rahman, K. Gudmundsson, M. S. Alam and K. M. Iftekharuddin "A new metric for 3D optical pattern recognition system," in Photonic Devices and Algorithms for Computing IV, K.M. Iftekharuddin and A. A. S. Awwal Editors, Proc. of SPIE, Vol. 4114, pp. 183-190, 2002.
3. A. A. S. Awwal, M. A. Karim, and S. R. Jahan, "Improved Correlation Discrimination Using an Amplitude-modulated Phase-only Filter," Applied Optics, Vol. 29, pp. 233-236, 1990.
4. M. S. Alam, A. A. S. Awwal, P. McWhorter, R. Venkatesh, S. Mathur, M. Dugar, B. Grewal, "Scale invariant amplitude modulated phase-only filtering," Optics and Laser technology, Vol. 32, pp. 231-234, 2000
5. K. M. Iftekharuddin, M. A. Karim, and A. A. S. Awwal, "Optimization of amplitude modulated Inverse filter," Mathematical and Computer Modeling, Vol. 24, pp. 103-112, 1996.
6. K. M. Iftekharuddin, M. A. Karim, P. W. Eloe, and A. A. S. Awwal, "Discretized amplitude-modulated phase-only filter," Optics and Laser Technology, Vol. 28, pp. 93-100, 1996.
7. J. P. Holman (in collaboration with W. J. Gajda), Experimental Methods for Engineers, Chapter 3-11, McGraw-Hill Book Co., New York, 1978.
8. Karl S. Gudmundsson, and A. A. S. Awwal, "Sub-imaging technique to improve POF search capability", Applied Optics, Vol. 42, pp. 4709-4717, 2003.
9. A. A. S. Awwal and H. E Michel, "Enhancing the discrimination capability of phase only filter", Asian Journal of Physics, Vol. 8, pp. 381-384, 1999.
10. Howard E. Michel, Enhanced Artificial Neural Network Performance using Multidimensional Complex Numbers, Ph.D. thesis (A. Awwal, advisor), 1999.

Enhanced Alignment Technique for the Final Optics Assembly (FOA) Beam

Wilbert A. McClay, James V. Candy, Mentor

UCRL-ABS-155661

The determination of the optimal centroid position of the Final Optics Assembly (FOA) Corner Cube is an area of active investigation for the automatic alignment of the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory. A new algorithm for determining the position of the FOA Corner Cube image was developed. It was compared to the existing FOA algorithm on 900 images. While the existing FOA algorithm is based on centroiding has a radial standard deviation of 2 pixels, the newly proposed algorithm based on classical matched filtering (CMF) and polynomial fit to correlation peak provides a radial standard deviation of 0.42753 three sigma for amplitude 200 rms noise 20 image. The new algorithm also addresses the angular displacement and spacing of the corner cubes. Thus, the requirements for NIF beam control indicate that the angle offset between the two corner cubes must not exceed ten degrees and the vertical spacing between the corner cubes must be between 150 and 220 pixels. If the input image parameters are different than the indicated beam control tolerance guidelines the FOA algorithm will immediately error-out.

The original FOA Corner Cube Algorithm was based on a template match in an expanded scale (factor of 5) with the template extracted from an actual image of a dual spot corner cube-centering image on a particular beamline. Since there was a possibility that both spots would be different due to mounting considerations, two templates were needed: the upper and lower template. The resolution of the approach was limited to only 0.2 pixels. The uncertainty was determined by running the algorithm on 900 simulated images with varying noise intensity and interference patterns.

The main problem with the current algorithm is that the images obtained from the real system undergo a certain degree of transformation due to defocus and other phase aberration, which cause the template not to match the real image. Therefore we are currently evaluating two competing approaches. The noise and uncertainty of these approaches are attached. The first one is based on smoothing the images with a defocus kernel. The second approach is based on designing an optimized match filter, which can tolerate a certain degree of variance. In the defocusing approach, the optical image is convolved with a point-spread function (psf). However, the point-spread function is manipulated in the phase domain and the phase transform is expressed in terms of the Zernike polynomials. The order of the Zernike polynomials determines the amount of phase domain aberration imposed on the image. For the first approach, the Zernike polynomials are raised to a polynomial degree of defocus. The methodology may initially sound counter-intuitive, but for the out of focus FOA images shown in Figure 1, the defocusing actually ameliorates the astigmatism by smoothing out the high frequency edge-like effects. Additionally, the defocus spreads the intensity of the region of interest such that a simple binary centroid may be imposed to find the exact center of the FOA Corner Cube.

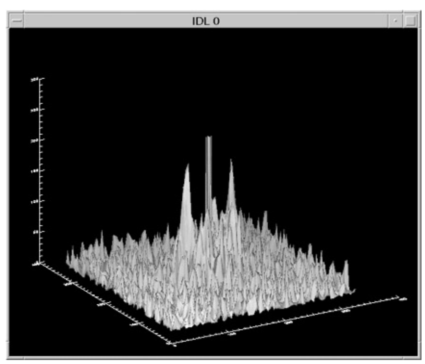


Figure 1. Original FOA corner cube algorithm surface plot amplitude 200 with rms noise 20.

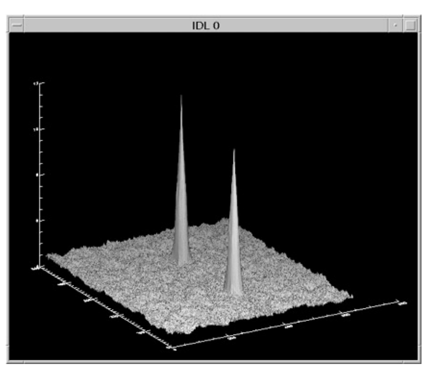


Figure 2. Advanced matched filter FOA corner cube algorithm surface plot amplitude 200 with noise 20.

NIF Optics Inspection (OI) Overview

Laura M. Kegelmeyer, Stephanie Daveler, Judy Liebman, Angela Jury, Walter Ferguson, Troy Vetsch, Charles Orth, Erlan Bliss and Thad Salmon

UCRL-ABS-155663

Thousands of optics for the National Ignition Facility (NIF) laser must be inspected to assure quality control and integrity of vacuum-loaded optics. Optics undergo inspection before going on the beamline to assure quality of manufacturing. They also are inspected while in situ on the laser beamline and then again when removed from the beamline. The Optics Inspection team is responsible for tracking the condition of optics through their lifetime. We have built a unified software system for all inspections that integrates image analysis and decision making using physical optics theory, data management for many terabytes of image data, and web browser based data visualization which brings analysis results to the customer's desktop. This overview will introduce the 7 different inspection areas and demonstrate the unified tracking and visualization capabilities of the automated optics inspection analysis system.

ImageJ Overview and Application Examples

Judy Liebman, Laura M. Kegelmeyer, Walter Ferguson, Karl Wilhelmsen, Holger E. Jones, Susan L. West

UCRL-ABS-155662

ImageJ is a versatile, freeware image processing tool which sports a friendly user interface. It is written in Java, and therefore can run on any operating system and can interface with other programs. For these reasons, ImageJ is a nice tool to have at your fingertips, and we have used it for NIF imaging in various guises. In this presentation, I will introduce ImageJ functionality and programming possibilities by displaying a few of the ImageJ programs that have been developed for NIF. Foremost are the ImageJ programs that have been built for the NIF control room operators to use during beam alignment. The operators were originally using ImageJ, due to its nice end user capabilities, to simply take a closer look at beam alignment images. We developed custom programs for ImageJ to assist the operators quickly and accurately in their assessment of beam alignment. Since the operators prefer the ImageJ GUI to the command driven IDL environment, we are also developing an IDL to ImageJ interface which will enable ImageJ to serve as a front end for IDL processing codes. In addition, we have developed many low level processing tools to supplement the built in ImageJ toolkit. These tools have been used in the programs for the control room operators as well as other applications in optics inspection. They can be made available to ImageJ users throughout LLNL. ImageJ's GUI is easily customized using Java's graphics library, Swing. We have developed various ImageJ programs to help us display our large optics inspection images. Other optics imaging teams have also found these programs useful. Finally, ImageJ can also be used effectively as a back end program for simple tasks. For example, in the optics inspection Perl codes we use system calls to ImageJ programs for certain image manipulations. Overall, we have found ImageJ to be a useful tool for many different areas of the NIF Imaging community.

Laser Performance Operations Model (LPOM): Tool to Automate the Setup and Performance Diagnosis of the National Ignition Facility

Michael Shaw

UCRL-ABS-155638

The Laser Performance Operations Model (LPOM) has been developed to provide real-time predictive capabilities for the National Ignition Facility at Lawrence Livermore National Laboratory. LPOM uses diagnostic feedback from previous NIF shots to maintain accurate energetics models for each of the 192 NIF beamlines (utilizing one CPU per laser beamline). This model is used to determine the system setpoints (initial power, waveplate attenuations, laser diagnostic settings) required for all requested NIF shots. In addition, LPOM employs optical damage models to minimize the probability that a proposed shot may damage the system. LPOM provides post-shot diagnostic reporting to support the NIF community, providing comparisons of beam energy, beam power and spatial profiles within minutes of the completion of a NIF shot. LPOM was deployed prior to the first main laser shots in NIF, and has been used to set up every laser shots in NIF's first quad (four beamlines). The parameters of the model (gains and losses) can be adjusted quickly using previous shot data, and, thus, provides accurate predictive capabilities for several different configurations of the NIF main laser amplifier. The use of LPOM has enabled routine achievement, to within a few percent, of goals for beam power, energy, and energy balance between beams.

Scientific Data Mining

Application of Dimensionality Reduction Techniques to the Analysis of Fusion Physics Data

Erick Cantu-Paz
UCRL-ABS-200540

Recently, a "quiescent H-mode" of operation has been observed in the DIII-D tokamak operated by General Atomics. During experiments with the tokamak, numerous sensors record vast amounts of data; is it not yet known which of these measurements captures the key characteristics of this mode of operation. We are investigating dimensionality reduction techniques to help scientists identify measurements that are related to this desired mode of operation. We will present preliminary results with statistical dimensionality reduction techniques and machine learning methods.

Robust Techniques for Background Subtraction

Sen-ching Cheung
UCRL-ABS-200371

Video is routinely recorded for applications such as security surveillance and traffic monitoring. Examining manually hundreds of hours of video to identify suspicious activities or traffic jam is extremely labor-intensive and error-prone. By using intelligent computer vision algorithms, many of these tasks can be automated. One of the fundamental tasks is to identify moving objects from the background scene, a task commonly known as background subtraction. There are many challenges in developing a good background subtraction algorithm. First, it must be robust against changes in outdoor illumination. Second, it should avoid detecting "pseudo-moving" objects such as swinging trees, rain or snow, and shadow cast by moving objects. Finally, it should be adaptive to objects moving at different speeds. In this talk, we will describe our recent research on robust background subtraction algorithms in the Sapphire project. We will present a number of highly adaptive algorithms for detecting moving vehicles and pedestrians in urban traffic video.

Statistical Approaches to Quantify Shape Similarity

Imola K. Fodor

UCRL-ABS-200370

Identifying objects in a large dataset that are similar to a given query object is a general problem shared by many scientific domains. In this talk, we address the specific case when the query objects are two-dimensional objects as parts of an image, the dataset is a large collection of images, and similarity is based on the shapes of the objects. We discuss statistical approaches to quantify the similarity between different shapes, and illustrate the methods in the context of comparing physics simulations to experiments. Our ultimate goal is to enhance the currently used "eyeball" measure with more quantitative measures of similarity.

Texture Features for Image Retrieval

Shawn Newsam

UCRL-ABS-200349

The automatic annotation and querying of images based on their content has received much attention over the past several years. This presentation focuses on the specific problem of using the low-level visual primitive of texture to perform similarity retrieval in large image datasets. We present current results, as well as describe ongoing research efforts in several application domains.

Applied Signal Processing/Control

Utilizing Commercial Graphics Processors for Real-time Geo-registration

Laurence Flath

ABSTRACT NOT RECEIVED BY AUTHOR

Intermittency in the Stable Atmospheric Boundary Layer Diagnosed with the Hilbert-Huang Transform

Julie Lundquist

UCRL-ABS-200790

The Hilbert-Huang Transform (HHT) allows analysis of intermittent, nonstationary, and amplitude-varying wave events in a time series. We apply the HHT to explore phenomena characteristic of the stable atmospheric boundary layer, using data from the Cooperative Atmosphere-Surface Exchange Study 1999 (CASES-99) field program. The HHT is first demonstrated with a five-day time series of temperature data. The technique allows simultaneous identification of the stationary diurnal temperature cycle as well as intermittent and nonstationary events such as frontal passages and density currents. The age of one density current is calculated from its dispersion characteristics, verifying that the density current in question results from rapid cooling near sunset.

The HHT is also applied to boundary-layer wind profiler data to identify inertial motions and explore their sources. Inertial motions (motions with local frequencies equal to the Coriolis frequency, also known as inertial oscillations) are present in this dataset. However, the times and levels of their manifestation, as revealed with the HHT, are inconsistent with the hypothesis that inertial motions are generated nightly during the evening transition of the boundary layer. Instead, the elliptical nature of the inertial motions suggests amplification by deformation frontogenesis.

A Discussion of the Theory and Effects of Sample Interlacing

Brian Guidry

UCRL-ABS-200775

To achieve high sampling rates, some digitizer manufacturers rely on the technique of sampling a signal using several slower samplers which have been staggered in time, and interlacing those samples to form the final signal. When the sets of samples are not staggered in time perfectly, unwanted artifacts can be seen in the final signal, and if the digitizer user is not aware that interlacing is being used, these artifacts can easily be mistaken for real data. We will briefly discuss the theory of sample interlacing, describe both quantitatively and qualitatively what the effects of sampler mistiming are, and discuss some ways to live with the side effects.

Numerical Back-propagation

Don Phillion

ABSTRACT NOT RECEIVED BY AUTHOR